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Contents :

"BROACHING—MACHINES, TOOLS & PRACTICE"

by E. PERCY EDWARDS, M.I.P.E.

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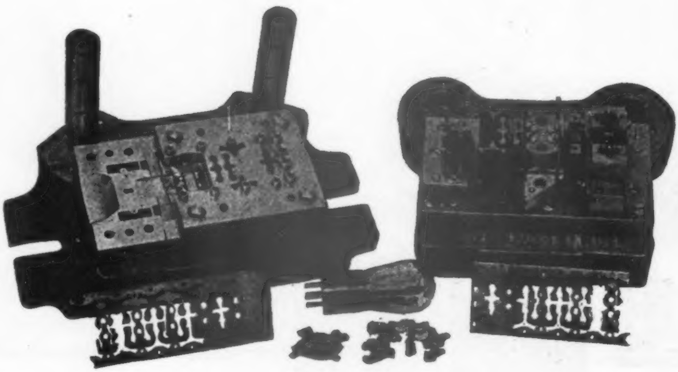

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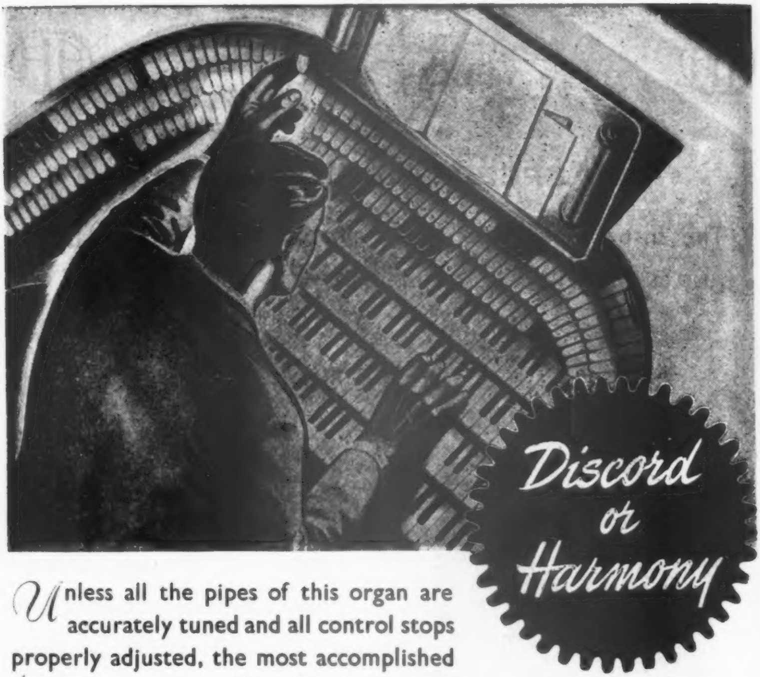
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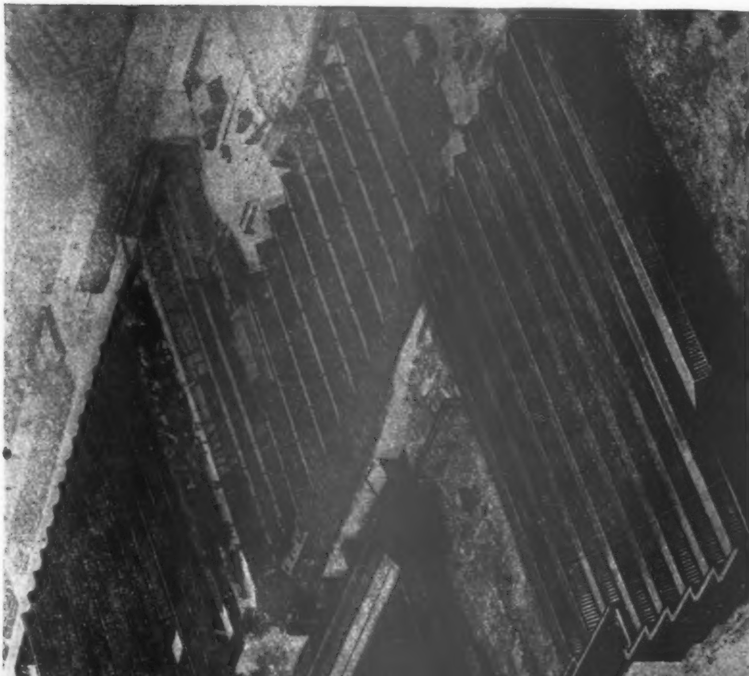
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INSTITUTION NOTES

November, 1946

November Meetings

4th Yorkshire Section. A lecture will be given by D. Clayton, Esq., D.Sc., A.M.I.Mech.E., F.Inst.Pot., on "Lubrication —Bearings and Gears," at the Great Northern Victoria Hotel, Leeds, at 7-00 p.m.

4th Coventry Graduate Section. A lecture will be given by W. A. Bennett, Esq., M.I.E.E., on "The Economics of Quality Control."

6th Lincoln Sub-Section. A lecture will be given by H. Eckersley, Esq., M.I.P.E., M.I.Mech.E., on "Developments in Metal Cutting Technique," at a joint meeting with the Grantham Engineering Society.

8th North-Eastern Graduate Section. A lecture will be given by J. H. Ayre, Esq., Grad.I.Mech.E., Grad.I.P.E., on "Some Principles of Moulding Tool Design for Plastics," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

9th Yorkshire Graduate Section. A lecture will be given by N. Sykes, Esq., Grad.I.Mech.E., Grad.I.E.E., Grad.I.P.E., on "Colour and Its Application to Industry," at the Great Northern Hotel, Bradford, at 2-30 p.m.

12th Wolverhampton Section. A lecture will be given by R. R. Sillifant, Esq., M.I.W., Member of the American Welding Society, on "Submerged Arc Welding," at the Dudley and Staffordshire Technical College, Dudley, at 7-00 p.m.

12th Birmingham Graduate Section. A lecture and film show will be given by Cincinnati Milling Machines, Ltd., on "Modern Milling Practice," at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7.15 p.m.

13th Luton and District Section. A lecture will be given by T. F. Swallow, Esq., on "Production Management and Control," at the Central Library, Luton, at 7-00 p.m.

13th Manchester Section. A discussion on "Machine Tool Users' Difficulties" will be led by W. N. Roberts, Esq., M.I.P.E., at the College of Technology, Manchester, at 7-15 p.m.

November Meetings—*Cont.*

14th London Section. A lecture will be given by R. K. Allan, Esq., M.I.P.E., A.M.I.Mech.E., on "Some Observations of Rolling Bearing Technique," at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

15th Western Section. A lecture will be given by H. Eckersley, Esq., M.I.P.E., M.I.Mech.E., on "The Manufacture and Application of Sintered Carbides," at the Grand Hotel, Broad Street, Bristol, 1, at 6-45 p.m.

18th Derby Sub-Section. A lecture will be given by H. K. Kennedy, Esq., Regional Technical Officer, Ministry of Labour and National Service, on "Training and Employment of the Disabled," at the Art School, Green Lane, Derby, at 6-45 p.m.

20th Birmingham Section. A lecture will be given by M. Riley, Esq., on "Examples of Detailed Design on Arc Welded Components," at the James Watt Memorial Institute, Great Charles Street, Birmingham, at 7-00 p.m.

20th Halifax Graduate Section. A lecture will be given by J. W. Wardrop, Esq., on "Lubrication," at the Technical College, Halifax, at 7-00 p.m.

21st Glasgow Section. A lecture will be given by F. J. Everest, Esq., on "Gear Cutting and Finishing," at the Institution of Engineers and Shipbuilders in Scotland, 39, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

21st Manchester Graduate Section. A lecture will be given by C. J. Dadswell, Esq., on "Drop Forgings."

22nd Eastern Counties Section. A lecture will be given by B. H. Dyson, Esq., M.I.P.E., F.I.I.A., on "Motion Study," at the Lecture Hall, Electric House, Ipswich, at 7-15 p.m.

23rd Yorkshire Graduate Section. A visit has been arranged to The Yorkshire Conservative Newspaper Co., Ltd., Leeds, at 2-30 p.m.

25th Halifax Section. A lecture will be given by J. G. Noble, Esq., A.M.I.Mech.E., A.M.I.Struct.E., on "Welding *versus* Casting and Riveted Structures," at the White Swan Hotel, Halifax, at 7-00 p.m.

November Meetings—*Cont.*

26th North Eastern Counties. A lecture will be given by C. Pearson-Smith, Esq., on "Capstan and Turret Lathe Tooling," at the Neville Hall Mining Institution, Newcastle-on-Tyne, at 6-30 p.m.

December Meetings

2nd Coventry Graduate Section. A lecture will be given by Sir Donald Bailey, O.B.E., on "The Bailey Bridge." Details not yet available.

2nd Yorkshire Section. A meeting has been arranged at which papers on "Relationship between Research and Production Engineering" will be presented by Messrs. W. Armstrong, C. L. David, and R. J. Mitchell.

2nd Derby Sub-Section. A lecture will be given by Dr. Mullins on "X-Ray in Industry," in the Art School, Green Lane, Derby, at 6-45 p.m.

7th North-Eastern Section. A Social Evening has been provisionally arranged.

7th North-Eastern Graduate Section. A Works Visit has been arranged. Full details are not yet available.

11th Luton and District Section. A lecture will be given by G. E. Windeler, Esq., on "Industrial Accidents," at the Central Library, Luton, at 7-00 p.m.

12th Wolverhampton Section. A lecture will be given by Walter C. Puckey, Esq., M.I.P.E., F.I.I.A., on "The Gap Between Production Engineer and Manager," at the Civic Hall, Wolverhampton, at 7-00 p.m.

13th Eastern Counties Section. A lecture will be given by Dr. W. Wilson, on "Electronics in Industry," at the Britannia Works, Colchester, at 7-15 p.m.

14th Western Section. The Eighth Annual Dinner will be held at the Grand Hotel, Broad Street, Bristol, 1, at 7-00 p.m.

14th Yorkshire Graduate Section. A lecture will be given by Lt.-Col. C. W. Mustill, M.B.E., A.M.I.Mech.E., M.I.P.E., on "Management," at the Great Northern Hotel, Leeds, at 2-30 p.m.

December Meetings—*Cont.*

16th Halifax Section. A lecture will be given by J. O. Cooke, Esq., of the British Standards Institution, on "Industrial Standardisation and the B.S.I.", at Whiteley's Cafe, Westgate, Huddersfield.

19th Glasgow Section. A lecture will be given by E. M. Trent, Esq., Met.Ph.D., and H. Eckersley, Esq., A.M.I.Mech.E., M.I.P.E., on "Manufacture and Application of Sintered Carbides," at the Institution of Engineers and Shipbuilders in Scotland, 32, Elmbank Crescent, Glasgow, C.2, at 7-30 p.m.

19th London Section. A lecture will be given by G. W. Nash, Esq., on "Production of Bevel Gears," at the Institution of Mechanical Engineers, Storey's Gate, St. James's Park, London, S.W.1, at 6-30 p.m.

Council Meeting

The next Meeting of Council will be held at 11 a.m. on 24th January, 1947, at the Institution of Civil Engineers, Great George Street, London, S.W.1.

Personal

Mr. E. J. H. Jones, M.B.E., M.I.P.E., Member of Council, has been appointed a Director of British United Traction, Ltd.

Obituaries

We deeply regret to announce the deaths of Mr. J. A. Rushbrook, Int.A.M.I.P.E., Works Manager of Messrs. Precision Bearings, Ltd., Greenford, Middlesex, and Mr. M. F. Rowe, M.I.P.E., of Burnwood, New South Wales.

Books Received

The Nature and Significance of Management, by E. F. L. Brech, B.A., B.Sc.(Econ.), M.I.I.A. Published by the Management Library. Price 5/- net.

Introduction to Production Control, by D. Tiranti, A.I.P.E., A.M.I.I.A., and W. F. Walker, A.M.I.P.E., A.M.I.I.A., Published by Chapman & Hall, Ltd., London. Price 15/- net.

Guide to Drawing Office Tracing, by P. W. Baker. Published by Sir Isaac Pitman & Sons, Ltd. Price 7/6 net.

BROACHING—MACHINES, TOOLS AND PRACTICE

By E. PERCY EDWARDS, M.I.P.E.

Presented to Wolverhampton Section, 20th June, 1946; Birmingham Section, 18th September, 1946; Leicester Section, 17th October, 1946.

This paper is intended as a survey of the whole field of broaching practice, rather than to deal with the subject in a highly technical manner, and to place before engineers the general principles involved, there apparently still being some misunderstanding regarding the possibilities of this method of machining.

Many regard broaching as a new idea, but, in fact, the practice dates back nearly 100 years. The derivative of the noun " broach " is undoubtedly the Latin word " brocca " or " broccus," meaning "a projection of teeth," and more latterly by the use in early English and French of the word " broche," meaning an awl, bodkin, or tool for the tapping of wine barrels.

Taper pin reamers having five or more sides are often described as " Lancashire " broaches, but, in the light of modern practice, this is a misnomer, and no reference is being made herein to this type of tool.

Historical.

Concerning the early history, Richard Lawrence at a rifle factory in U.S.A. in 1853, and using a hand press, pushed round and serrated balls through heated gun barrels to size, or rifle them, and this process was continued during the Civil War of 1861-1865, while a hand-operated broach was developed about this time in this country and in Europe, also for sizing gun barrels, some of which were sent to America during the Civil War. In 1870 a patent was granted for a multi-toothed cutter-bar for producing keyways, and in 1873, another patent was granted to A. P. Stephenson for an improvement in broaching machines, which appears to be the first official use of the word " broaching."

About the same time, a tool was developed for machining the bore of bearing brasses made up of multi-discs threaded on an arbor and used in a press—this being the forerunner of the " built-up " broach.

While surface broaching is a more modern development, there are known examples as early as 1882, there being a record of a

machine being patented in America in that year, and in 1888 a further patent was granted for a method of surfacing and sizing wrenches by surface broaching in one pass.

The birth of modern internal broaching dates back to 1898, when J. N. Lapointe departed from the rack and pinion type of machine and produced the first machine operated by screw and nut, which set a new standard in production for both speed and accuracy. This led in 1902 to the incorporation of the first organisation specifically formed to develop the practice of broaching as now understood, and Fig. 1 shows one of the earlier screw and nut type machines manufactured by the Lapointe Company. This was belt-driven, operated from a countershaft, and fitted with a clutch and heavy flywheel.

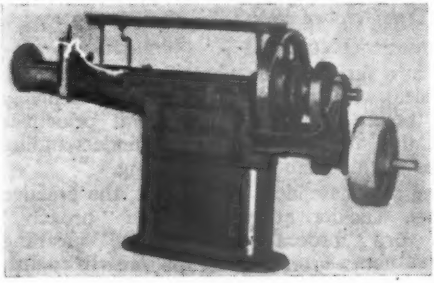

FIG. 1.

By way of comparison, Fig. 2 shows the development which has taken place, and illustrates a modern self-contained hydraulically operated, and electrically controlled machine of fabricated steel construction.

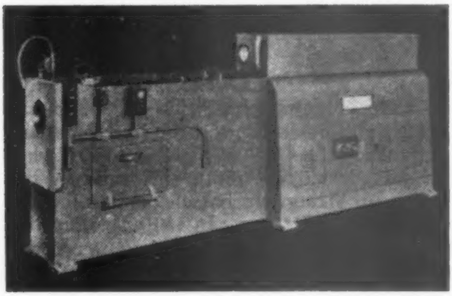

FIG. 2.

From plain bearings and keyways, there was a natural development to the machining of internal square holes for sliding gears, and by 1910, still further advancement to multiple splines.

About 1914 the first Duplex Horizontal Screw operated machine made its appearance, and during the war which commenced in that year, considerable impetus to many new or improved methods of machining followed, and broaching was one of those which came into greater use. The rifling of gun barrels on production lines dates from this period, ball-bearing thrust pullers being used for the first time as a means of producing the necessary helix in the bore.

Further developments at this time were the use of cutter-bars having inserted teeth, and the commencement of what is now almost universal practice, that of the use of high speed steel broaches in place of those made from either cast-steel or case-hardened mild steel. The first horizontal hydraulically operated machine was manufactured about 1921 by the Oilgear Company, and this established a notable advance in broaching practice, with increased cutting speeds and improved tool life.

For some time, however, controversy raged amongst engineers, particularly in this country, as to the merits and de-merits of hydraulically operated machines as compared with the screw type, doubtless caused by the disadvantages common to hydraulics depending on accumulators for finally supplying power. This had, however, been revolutionised so far as machine tools were concerned by the introduction of the self-contained motor-driven unit pumps, using oil as a fluid instead of water. The controversy gradually died down, new competitors came into the field, and today the great majority of horizontal broaching machines, and all vertical machines are hydraulically operated.

While surface broaching has developed more slowly in England as compared with U.S.A. where quantity production made it a necessity, it received a definite impetus everywhere during the war just concluded. In America and Europe, but still to a lesser degree here, broaching—and particularly surface broaching—was used to a considerable extent ; indeed, so much so that not a single machine gun, rifle, aeroplane engine or fuselage, transport vehicle, electrical or hydraulic device was produced that did not, at some stage in manufacture, depend upon broaching. In machine design, further innovations have been made which will be referred to later.

Advantages and Disadvantages.

Having completed a brief historical survey, we will now consider the subject more fully, firstly examining the reasons for, and the advantages and disadvantages of broaching. It will doubtless be agreed that in tool production, or indeed, in most engineering practice, it is easier accurately to produce external forms than internal, particularly where hardening and grinding are involved. The internal broach, therefore, lends itself to comparatively easy manufacture, and once produced continues to reproduce its form in the work-piece over very long periods in terms of quantity, is easily reconditioned when its cutting edge is dulled, and the accuracy of the final product is maintained because only the few finishing teeth need to be of exact size and form required, and these are not subjected to the same hard usage met with in other machining methods.

The fact that different roughing and finishing teeth can be combined in one set-up is obviously an advantage, and generally allows of faster stock removal than other metal cutting processes. Individual cutting teeth only being in contact with the work for such a brief period, removing a pre-determined and relatively small amount of stock, there is a minimum of frictional resistance and consequent heat absorption.

For these reasons correctly designed broaches should produce more components than tools of other types.

The maintenance of dimensional accuracy and tolerance has already been referred to, other advantages being the high finish obtainable, and the fact that often combined machining operations—for instance, internal and surface broaching, or machining in different planes in correct dimensional relation to each other—can be performed.

Disadvantages are :—

(1) Unsuitability for large stock removal.

(2) Not being applicable where there is any obstruction to the passage of the broach in relation to the work-piece, although consideration of component design will often obviate this.

(3) Not always economical where only small total production is called for.

(4) If only small batches at long intervals are required, due to economic considerations.

Conversely, there are many cases where broaching offers the only economical method even for small quantities ; examples being regular or irregular shaped holes, spline, or spiral spline holes, and serrations.

In surface broaching the only likely deterrent will be the original cost of the machine rather than the tooling.

Types of Machines.

The table below shows the range of machines available with their main and sub-divisions and each of these will now be considered.

TYPES OF BROACHING MACHINES

1 · HORIZONTAL · HYDRAULIC AND MECHANICAL

(A) SINGLE RAM (OR SCREW)
(B) DUPLEX RAM (OR SCREW)
(C) · DRUM OR TURRET
(D) SPECIAL · MOSTLY SURFACE BROACHING OR RIFLING

2 · VERTICAL · HYDRAULIC

INTERNAL	SURFACE		COMBINATION
a. PULL UP	a. SINGLE SLIDE	1. FIXED WORK TABLE	TWO-WAY AND THREE-WAY MACHINES
b. PULL DOWN		2. SHUTTLE WORK TABLE.	WHICH MAY BE USED AS
c. PUSH DOWN	b. DUPLEX SLIDE	SHUTTLE WORK TABLES	PULL DOWN AND PUSH DOWN
		ALTERNATING WITH	INTERNAL, OR SLIDE TYPE
		BROACH SLIDES	SURFACE WITH FIXED TABLE

FIG. 3.

It will be noted that practically all the illustrations used are of hydraulically operated machines, as this type is now mostly used, for the following reasons :—

(1) Infinitely controllable speed and power, both in the cutting and reverse strokes.

(2) The cushioning effect produced by the compression of the operating fluid power.

(3) The known and controllable load on the broach.

These advantages, entirely absent in screw and rack operated machines, will be enlarged upon later.

Horizontal Machines.

Fig. 4 shows a typical single ram machine in which the adjustable puller is held in a crosshead supported on hardened and ground slides having adjustable bronze shoes to take up wear. The pump and motor are mounted inside the main frame at the rear of the machine on a platform formed by the top of the hydraulic oil-tank, all piping and valve gear being contained within the frame. The push-button control, coolant supply piping, and pressure gauge can be seen, the operator's unrestricted view of the latter being of importance.

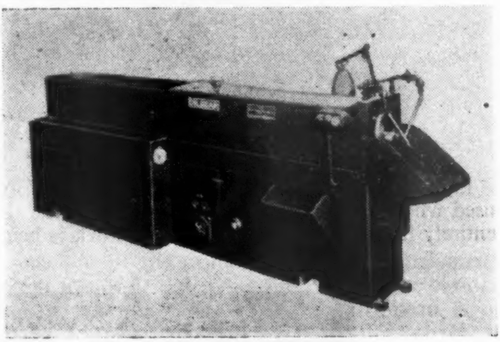

Fig. 4.

Fig. 5 shows, on a similar machine, the vertical adjustment to the crosshead, the hardened steel ways and the key type broach puller at the left-hand side, and on the right, fitted to auxiliary ways, the broach support fixture for use with heavy broaches. The filter tray in the centre collects the larger

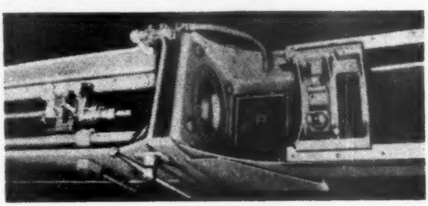

Fig. 5.

chips which fall from the broach, and in the main bushing seen in the work-head, auxiliary bushings or fixtures can be fitted according to work-piece requirements.

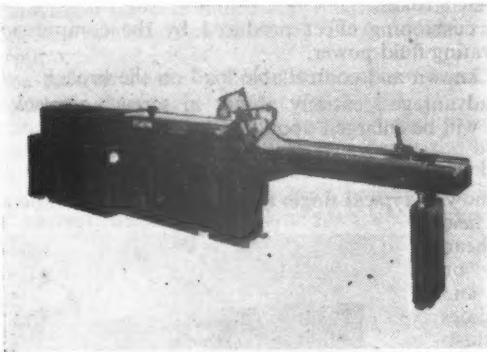

FIG. 6.

Fig. 6 illustrates more fully the broach support trough, which is used when handling heavy and long broaches. It can be removed entirely if required, when only short work is being dealt with.

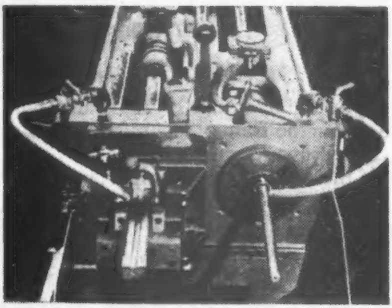

FIG. 7.

Fig. 7 is a duplex horizontal machine, showing on the one side an internal set-up, whilst the other head is being used for surface broaching. On the right, an internal broach is producing two king-pin holes of ·828 in. dia. in a steering wheel knuckle, and the left-hand tools are broaching the inside surfaces of the bosses on a front

axle fork, one of the components being in the fixture, while one completed will be seen immediately above. The fixture is fitted with hardened and ground guides to the broach.

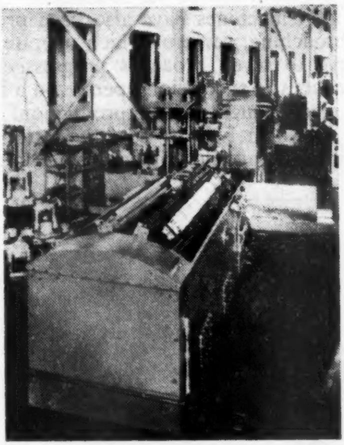

FIG. 8.

Fig. 8 shows a machine of the drum or turret type, the turret holding eight different sets of broaches—in this case for the various contours in a machine-gun breech block. The work-head is of shuttle type, loading and unloading being performed alternatively at either side.

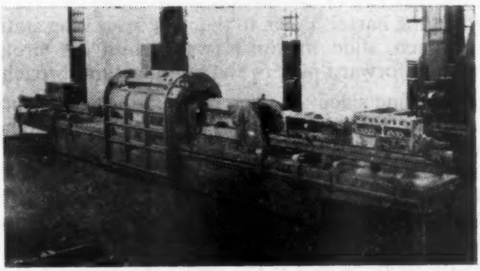

FIG. 9.

Fig. 9 is of a special horizontal surface broaching machine used for machining cylinder blocks. The broaches are suspended in the crosshead fixture and remain stationary during the cutting cycle,

the blocks being fed by a roller conveyor into the fixture shown at the right-hand side of the broach head, which then traverses under the broaches, the completed block being removed on to a similar conveyor at the left-hand end of the machine.

Special horizontal machines have also been produced for rifling gun-barrels by broaching, some of which operate on one barrel at a time, using five to seven broaches progressively, while others, using several broaches in succession operate on a number of barrels simultaneously, giving much quicker production.

The machine shown in Fig. 10 is of the latter type, having five broaching and one loading and unloading position, the final broach also sizing the bore. Barrels up to 37mm. bore are broached on this machine.

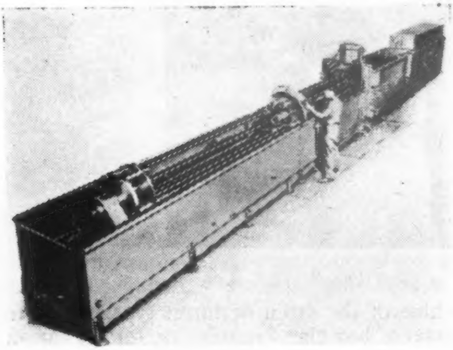

FIG. 10.

The components are loaded into the indexing work holder and the five broaches pulled through the barrels simultaneously. At the end of each stroke the work-head is indexed to a position half-way between the broaching stations, and the broaches are then automatically pushed back through return tubes into the broach pullers at the rear end of the broach slide. They are retained in this position while the barrels index to the next broaching station, whereupon the broach slide moves forward until the broach shanks engage with the forward pullers and complete the broaching stroke.

The barrels being rifled are each rotated during the cutting stroke in relation to the helically arranged teeth on the broaches through a suitable train of gears, operated from a spiral shaft and nut situated in the centre of the work-head. This shaft is secured to the broaching head of the machine and is drawn axially through the work holder during the broaching operation, simultaneously with the broaches.

The coolant fluid—which is fed under pressure—is automatically controlled so that it is only supplied during the forward stroke.

Production as high as sixty barrels per hour is possible by this method.

While considering helical broaching, it should be remembered that

components having an internal helix not exceeding 8 degrees lead, and in which the width does not greatly exceed the bore diameter, may be broached without any leader other than the broach itself, provided the work is supported in a fixture having a ball thrust bearing.

Vertical Machines.

Fig. 11 shows a simple type of vertical pull-up machine used for internal broaching. The component is threaded on to the broach pilot, while the broach is in the lower stationary position, in such a manner that it will cause it to contact the underside of the crosshead

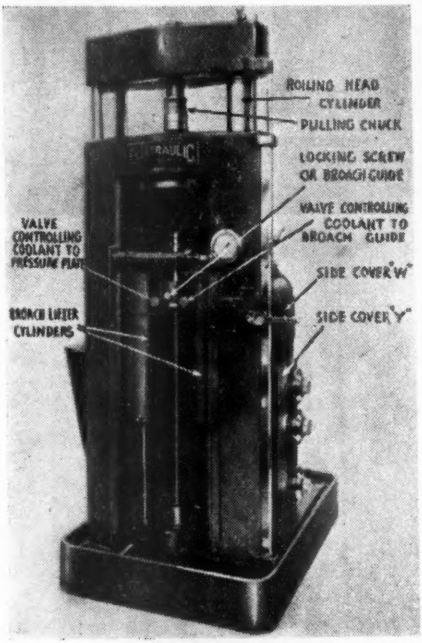

Fig. 11.

or table when the broach puller rises. At the end of the stroke the component is removed either manually or by means of a chute, and the broach then returned to the starting position.

Fig. 12 shows the same machine in use on a cluster gear blank, where, due to the component being of a heavy character, a simple fixture is used to locate it during the broaching operation.

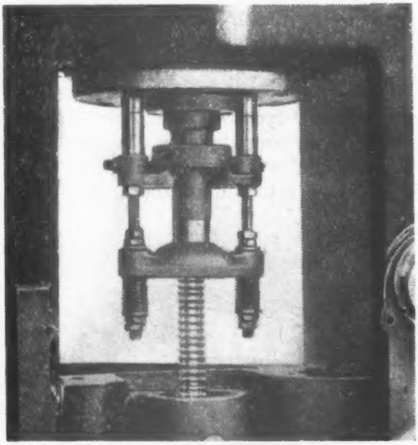

FIG. 12.

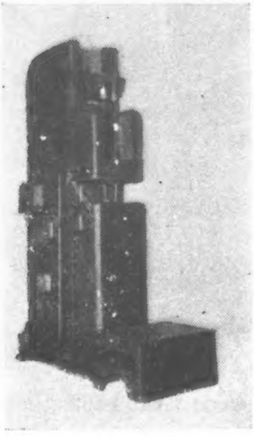

FIG. 13.

Fig. 13 is another example of a pull-up type machine, with two broaches in operation simultaneously.

Fig. 14 is a close-up view of a push-down machine being used with multiple broaches, four of which are used simultaneously in broaching bores in distributor cams. A hand-operated indexing fixture is used, four components being loaded during the cutting cycle on another four. A high finish to a close tolerance being necessary, burnishers are included at the finishing ends of the broaches. The broaches are returned automatically to the upper head, while the indexing fixture is at right-angles to the operating position. Production 500 per hour.

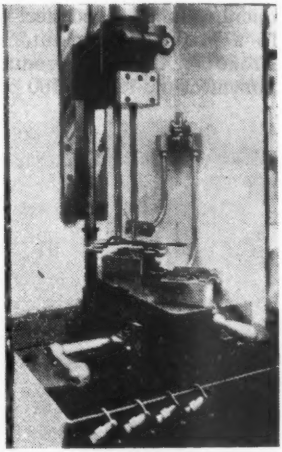

FIG. 14.

Fig. 15 shows another push-down type machine, simultaneously broaching on the left-hand side, a 36 serration bore in rocker arms,

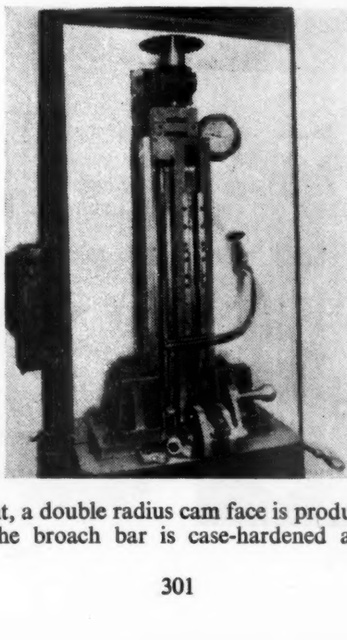

FIG. 15.

while at the right, a double radius cam face is produced on the same component. The broach bar is case-hardened and ground and

operates in hardened steel ways, while the serration broach is fitted to a holder having automatic broach return mechanism. Each stroke of the ram produces progressively one completed component at the rate of 160 per hour.

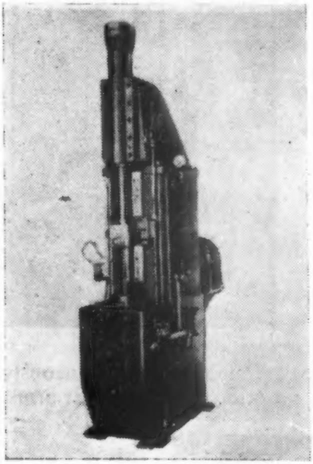

Fig. 16 shows a broaching press of push-down type in which the broach can be handled manually, or, if required, automatic broach-handling can be fitted.

There are a number of different pull-down type machines, some of which are especially suitable for particular operations, and Fig. 17 illustrates a high production machine, in which four broaches are cutting keyways in four gears simultaneously. This type is used mainly for work requiring comparatively short strokes.

FIG. 16.

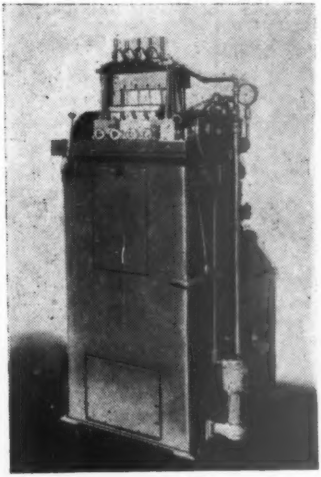

FIG. 17.

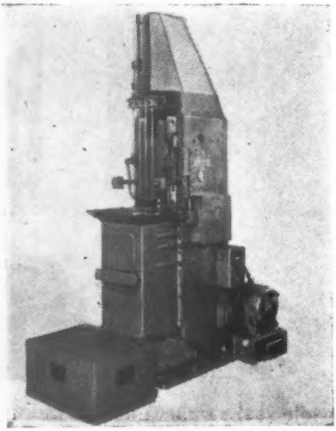

FIG. 18.

Fig. 18 is of a machine suitable for longer strokes, and either one or more broaches operating at the same time, the broach handling being entirely automatic. In this case, four broaches, cutting key slots in rifle receivers, are used—production being about 750 per hour.

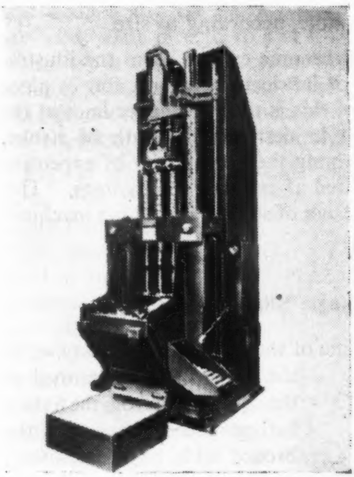

FIG. 19.

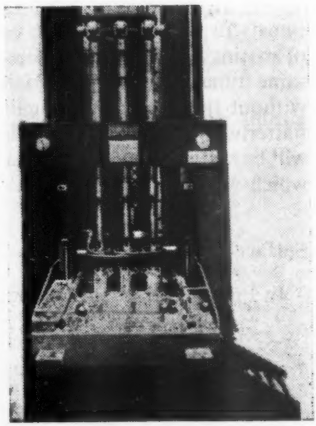

FIG. 20.

Figs. 19 and 20 show an interesting machine, which, while corresponding to a pull-down machine, operates somewhat differently in that the broach, or broaches, remain stationary during the cutting portion of the stroke, while the work is drawn upwards on a rising table.

Referring to the close-up (Fig. 20) three starter motor yokes, or dynamo bodies are loaded at the front end of the table—(in practice there are never six components as shown, these being for the purpose of illustration only) the latter then being pushed to the rear position under the broaches, this automatically tripping a switch which starts the machine cycle. At the completion of the cutting stroke the broaches are released at the upper end, and an ejector mechanism pushes the work-pieces forward to the front of the table, clear of the broaching position. The table descends and simultaneously the upper ram also descends to retract the broaches and return them to the starting position. The table having descended, the components are automatically ejected through an orifice at the right-hand side of the machine on to a roller-track, and thus to the

next operation. Due to the heavy cutting and high production (the average cycle time being less than 30 seconds) swarf is collected on an automatic conveyor underneath the machine, and carried to its rear. The whole of the machine cycle is hydraulically operated and electrically interlocked, the operator only needing to load the three components at the front end of the sliding table. Production is four to six components per minute, according to size.

One of the features which will become evident from the illustrations will be the increasing use of fabricated construction in place of castings. The general effect of this is to give cleaner lines at the same time allowing of variation in design and length of stroke, without the necessity for maintaining the multiplicity of expensive patterns, which would be required if made from castings. This will be still more evident in the design of surface broaching machines which will now be considered.

Surface Broaching Machines. Single Slide.

In Fig. 21 will be seen a machine of the fixed work-table type, its use requiring the removal of the component from the fixture before the return of the broach slide, or alternatively, mechanism built into the fixture for withdrawing the component from contact with the broaches during the return stroke. This usually means that automatic cycle cannot be fitted, with consequent lower production. It is, however, suitable where capital cost is a serious consideration.

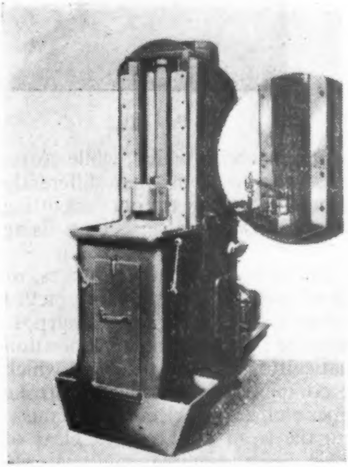

FIG. 21.

The illustration is a development of this type to a three-way machine, enabling it to be used as a push-down or pull-down internal or surface broaching machine of the fixed table type, its use for surface broaching being shown in the inset view.

Machines With Shuttle Table.

Machines having shuttle tables, while higher in capital cost, are those more generally used where high rate of production is involved, as not only is time saved during the return of the broach slide, but often the movement itself can be used for the purpose of clamping and unclamping the work-pieces. Various methods of shuttling are used, some directly to and from the broach slide, others around trunnions in either the vertical or horizontal axes, or in transverse relation to the broach slide. In all such cases the slide, with fixtures, returns to the unloading position prior to the broach slide return, the complete cycle being entirely automatic.

Fig. 22 shows a single-slide machine with a to and fro shuttle table which contacts adjustable stops, the cycle being commenced by the operator simultaneously pressing the two push-buttons to the left and right of the broach slide—a desirable safety precaution, as neither hand is left free.

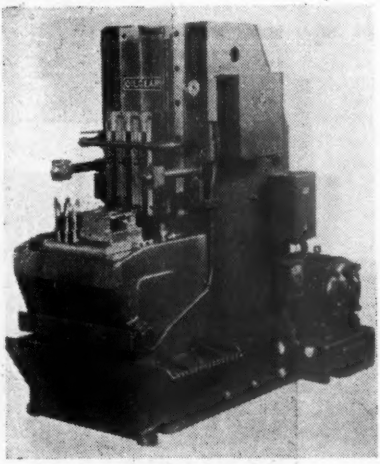

FIG. 22.

It is essential with all types of moving work-tables that the forward position is held in such a manner that the resultant broaching force will not cause it to move away. Movements as small as .0002/.0005 are sufficient to produce bad results.

A satisfactory means of overcoming this deflection is to hold the table forward against its stops with a pressure greater than that exerted by the broach, thus transferring the deflecting force from the table stops to the broach slide during the cutting portion of the cycle.

The operation being performed is that of broaching two flat surfaces on each of three rifle receivers—they are carbon steel forgings, and production is 600 finished parts per hour.

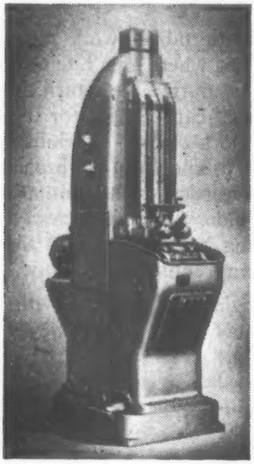

FIG. 23.

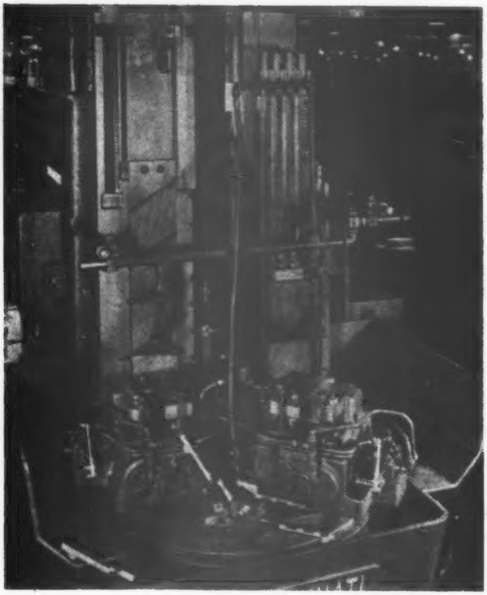

FIG. 24.

Fig. 23 is of a single-slide machine having two broaching positions in which the fixtures move to and fro, round a horizontal trunnion.

Double Slide Machines.

Fig. 24 illustrates a machine in which the fixtures, mounted on an auxiliary table, are presented alternately to each of the broach slides, around a vertical axis, the operation being in unison with the broach slides.

Two operations are broached progressively on the ordnance rod handle, seen at the bottom of the picture. The operator loads one fixture while the component in the other is being machined. Production 157 components per hour. A limit switch control is fitted to ensure correct loading before each succeeding cut can be commenced.

In Fig. 25 the machine is again of the Duplex Slide type, but in this, the fixtures move away laterally from the broach slides, in unison with them to permit of free return of the broaches. The whole operation is hydraulically controlled and interlocked, as also is the clamping and unclamping of the components held in the fixtures.

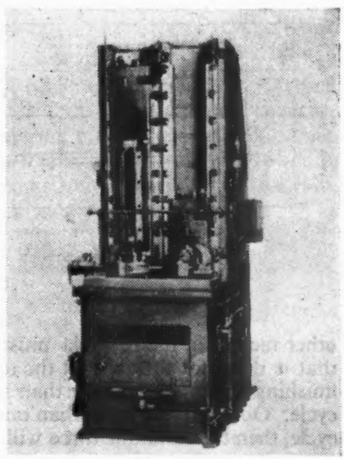

FIG. 25.

Machine Selection.

Having considered the various types of machines available, some attention may be given to the selection of one suitable for the work to be done.

Firstly, the length of stroke required must be established. This will be governed by the maximum stock removal, the rise per tooth, tooth pitch, and length of component. To this dimension must be added sufficient to clear components and fixtures.

The number of broaches to be used simultaneously in internal broaching, or the choice of single or duplex slides in surface broaching, will depend on output required and the number of separate operations to be performed. Having determined these, the power capacity of the machine can be established.

A formula for arriving at the maximum force required in 100,000 pounds units will be :—

$$N \times C \times W \times K$$

when

N = number of teeth cutting at one time.
C = thickness of chip per tooth.
W = width of face.
K = constant.

Fig. 26 shows the value of " K " for various sizes of chip and materials, and it should be noted that increase of chip thickness does not necessarily increase load. From the graph it will in fact be seen that the force required to remove metal increases as the size of chip decreases, and that when the chip is less than ·005 a considerable increase of force is necessary. In considering this, however, the other factors in the formula must be taken into consideration, so that it does not follow that the total power required is more at the finishing end of the stroke than it was in the earlier portion of the cycle. Obviously, if more than one operation is being performed per cycle, then the resultant force will be proportionately increased.

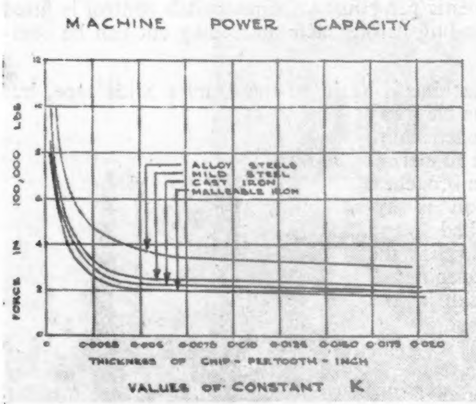

FIG. 26.

The use of calculated force is only practicable in the case of hydraulic machines, as there are no means of satisfactorily registering the pull exerted by mechanically operated machines.

It is good practice for machines to have reserve power and excess length of stroke, as these can always be adjusted to suit conditions, whereas overloading can only be dealt with by increasing the number of internal broaches used per set, or cycles of the broach slide in surface work. The extra capital cost of increased power and length of stroke is usually relatively small.

Broaches and Broach Design.

It will be appreciated that the types and forms of broaches are infinite, but the main classifications are :—

1. *Method of Operation.*—Push or pull.
2. *Type of Operation.*—Internal or external.
3. *Construction.*—Solid, built-up, or inserted tooth.
4. *The Operation Itself.*—Hole, spline, serration or combination of these, spiral or rifling, surface broaching, etc.

Most internal broaches are of pull type, particularly where broaching machines are being used, the component frequently being completed in one pass by one broach only.

Internal push broaches are useful for sizing operations and can be used where presses of comparatively short stroke only are available. Compared with pull broaches, the stock removal per broach is small. A good example of the use of push broaches is in sizing, correcting or burnishing holes in previously heat-treated components such as gears.

Fig. 27 shows a typical internal broach, the essentials of which, other than dimensional accuracy, are a straight and suitably toothed tool having a pull or push end, entering pilot, roughing teeth, semi-finishing teeth, and finishing teeth—the latter sometimes followed by burnishers. In the case of heavy horizontal broaches, a following

FIG. 27.

pilot or grip diameter is also necessary as support for the weight, or as a guide, and this usually leaves the support after the last finishing tooth has passed through the work-piece. A following pilot or guide is also used on many vertical internal broaches, particularly where automatic broach handling is fitted.

The number of roughing teeth is determined by the material to be cut and the amount of stock to be removed, intermediate teeth again by the material and also the finish required, and the number of finishing teeth, by the length of the work-piece, finish, and accuracy necessary.

The elements of tooth design will be seen in Fig. 28 and in detai' are as follows :—

Front rake or hook angle governed by the hardness and kind of material in the work-piece, the angle varying from approximately 6 degrees in the case of cast-iron or hard steel, to as high as 20

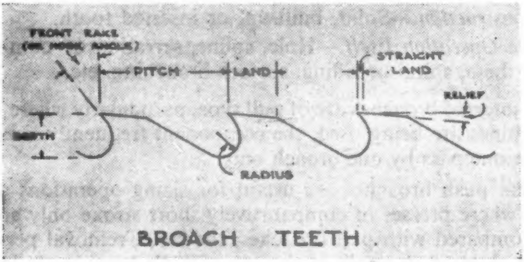

FIG. 28.

degrees for very soft steel, whilst aluminium may require 10 degrees or more, depending upon any alloyed content. In the case of hard brass the front rake may vary from 5 degrees through zero to as much as 5 degrees negative.

Pitch is dependent upon the length of the component to be broached, the nature of the material, and the size of chip removed, a good approximation being based on the formula :

$$\text{Pitch} = \sqrt{\cdot 35 \text{ length of cut.}}$$

In considering this in relation to components of shallow depth and to improve cutting conditions, attention should be given to the desirability of stacking the components whenever possible.

Straight land—this should be kept as short as possible, having due regard to the life of the tooth occasioned by regrinding the front face, and may be more in the roughing teeth, but less in the finishers. Generally, it should be of a length of ·01 in./·02 in. in the roughing teeth, decreasing to as little as ·005 in. in the finishing teeth.

Some slight backing-off of the straight land is necessary, again varying between the roughing and finishing teeth ; for the former it might be from ½ to 2 degrees and the finishers ½ to 1 degree. If left quite parallel there is always a danger of this becoming negative, due to frictional load.

Land—the total width of tooth including straight land and relief.

Relief—the clearance behind the straight land to give maximum support without imposing any frictional load.

Radius—this is extremely important and is necessary to cause the

chip to curl, thus preventing the chip crowding in the tooth space. The surfaces should be smooth and free from wheel abrasions.

Depth of tooth—this is governed by the pitch and chip space required and must be sufficient to prevent any crowding of swarf in the space available.

Fig. 29 shows correct chip formation produced in a section of a broached hole and also in a keyway. Referring to the upper view, the effect of the correct chip breaker nicks can be seen, the necessity for which would not arise in the lower example unless the keyway was wide and deep. Careful attention must be given to the proper positioning of the chip breaker nicks so that the succeeding teeth overlap the nicks in the previous teeth. Obviously, there can be no nicks in the finishing teeth, but this is immaterial owing to the small amount of metal removed.

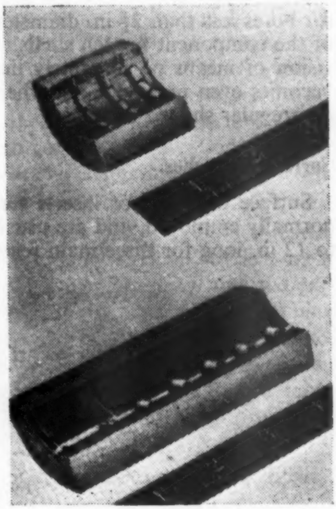

FIG. 29.

In Fig. 30 a correctly formed steel chip is shown in the upper left-hand corner, while in the lower can be seen the effect of insufficient tooth spacing, resulting in the breaking up of the

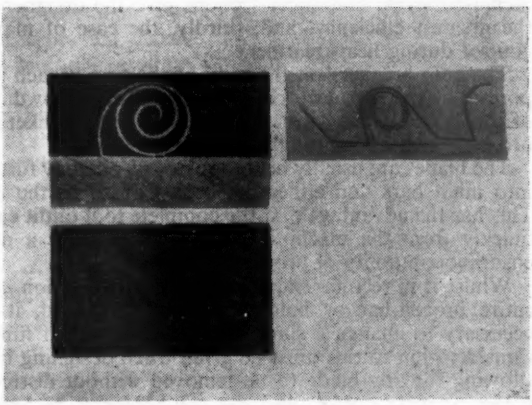

FIG. 30.

chip. This may cause crowding and possible breakage of the broach teeth. The right-hand view shows a chip in the act of forming, and clearly illustrates the importance of the root radius in chip formation.

Regarding built up internal broaches, these are rarely economical for bores less than 2½ in. diameter, owing to the cost of production of the component broach shells and arbors, and the necessary provision of means of accurately lining them up with each other. It becomes even more difficult when dealing with serration or spline, or irregular shaped broaches.

Surface Broaches.

Surface broaches or inserts seen in Fig. 31 are typical of those normally employed, and are usually made up in short sections 8 in. to 12 in. long for three main reasons.

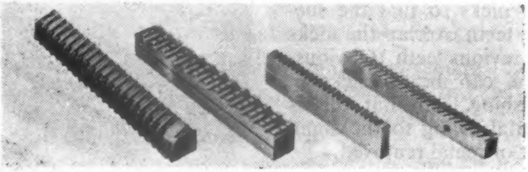

FIG. 31.

Firstly, the ease and cheapness of replacement, secondly, the increased scope that short sections give the designer to work with the greatest efficiency, and, thirdly, the ease of manufacture and control during heat-treatment.

The chip breakers on the radii of the first broach shown are important as there is always a tendency for chip crowding in broaches of this type. In the second example suitable breakers are seen in a broach which has a straight face.

The blades are usually held in sub-bars, possibly further assembled into main bars and either are bolted direct to the machine slide. This has the advantage that the complete tool outfit can be removed quickly from the machine, and be replaced by a duplicate, thus ensuring continuity of production.

Whilst it is recommended that under production conditions, the entire broach-bar or holder should be changed, it is sometimes necessary to change a single broach blade, or, if fitted, a sub-bar. Consideration to this must be given when designing broach bars by allowing for any blade to be removed without disturbing the sub-holder or main holder, and any sub-holder to be removed without disturbing the broach blades and main holder.

In high-production factories three complete tool outfits are often kept, the object being always to have a spare set in tool stores ready for use, while the other two sets are respectively on, or adjacent to production, or in the rool room being reconditioned.

The arrangement of the broach blades in the broach bar has to be considered in the early design stage. It should be remembered that when a broach is in operation a multiple set of forces are at work depending on the particular operation of each broach blade. The blades should be arranged in the bars in such a manner as to minimise as far as possible any high concentration of forces at any one point on the bar, particular care being taken to have the smallest possible forces acting at the finishing section.

It is therefore often good practice for the finishing broach blades to be entirely separated from the roughing broaches by leaving a gap which is known as a de-stressing gap. The length of the gap should be at least equal to the length of work, and if the machine is running at high speed, a slightly greater gap may be advisable. It is desirable that the broaching force and the resulting cutting forces should be kept as steady as possible, and therefore, if more than one line of broaches are in operation together it is preferable that they be staggered.

Careful attention should also be paid to the design of broach bars, since they have to transfer the cutting force from the machine to the broach blade and also hold the blade rigid to prevent deflection under the multiple resultant forces. The maximum mass of material should be allowed in the broach holder to absorb any small vibration that might be transferred from the broach blades. Consideration must also be given to avoid the holders becoming too heavy to be reasonably handled for broach changing.

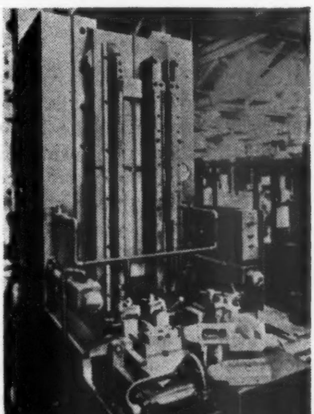

Fig. 32.

Fig. 32 is a typical example where inserts are mounted on sub-bars, the latter being attached direct to the broach slide of the machine.

Fig. 33 illustrates where a number of sub-bars have been assembled in the main bar shown, the whole being in turn attached to the machine broach slide. On the right half of this broach outfit will be seen a satisfactory method of dealing with comparatively wide,

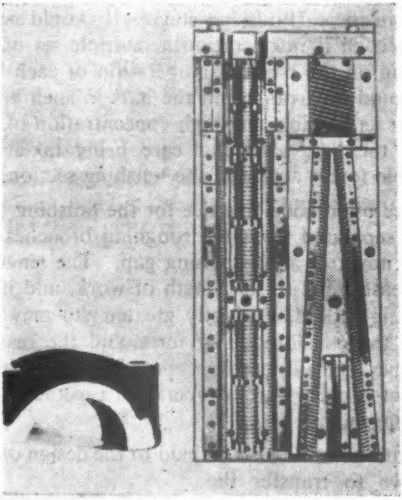

FIG. 33.

flat surfaces; a progressive broach is used, arranged in two lines at an angle to the vertical axis, but entirely covering the component during the passage of the broachslide. Each tooth cuts almost to full depth, a short full-width finishing section, which, if required, may be in tungsten carbide, being used at the end of the stroke. The short broach shown at bottom centre, covers the portion of the stroke which would be missed by the apex of the angular broaches. This method is not satisfactory for steel and high-tensile materials, but is specially useful for cast iron.

When dealing with fairly large flat surfaces, it is an advantage to form teeth at an angle to the axis of the broach, thus preventing shock as each successive tooth commences to cut.

An example, which is the face of a cast iron pump body, shown at the front corner of the machine table, will be seen in Fig. 34.

Many methods of fixing broach blades to the holder have been

used, and each has merit for a particular application—there is no one method which can be recommended for universal use.

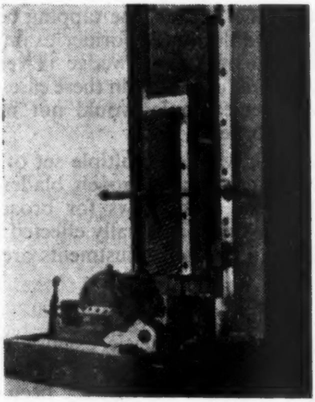

Fig. 34.

Fig. 35 illustrates some of the more suitable means available.

Wherever possible, any method of attachment where tapped holes are required in the broach should be avoided.

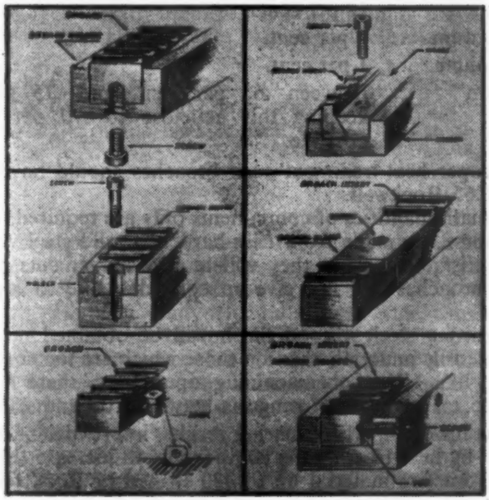

Fig. 35.

Two of the examples shown use screws direct into the broach section, in the one case the broach itself being tapped, while the other, where more metal is available, in the broach holder, has a counter-bored hole in the broach, the tapping being in the holder. This obviously is preferable to the former example. The method where the insert is held by a taper wedge is very satisfactory, as also that where a clamp is used, but in these cases accurate fitting is essential. The two lower examples would not be very satisfactory where heavy cuts are to be taken.

On some applications, where a multiple set of broaches is used, it is advisable to provide certain Broach blades with adjustment relative to one another. This allows for broach wear and also initial setting ; the adjustment is usually effected by taper gibs, but lateral direct reading micrometer adjustments are most useful.

Use of Broaches.

With all cutting tools certain basic essentials are necessary to obtain satisfactory results.

The correct design of broach has already been considered, other factors being the material from which the broach is manufactured, the nature of the material to be cut, cutting speeds and coolant supply. Experience has shown that the most satisfactory material for broach manufacture is 18-4-1 with a closely controlled carbon content. The analysis therefore should be :—

Tungsten	...	18 per cent.
Chromium	...	4 per cent.
Vanadium	...	1 per cent.
Carbon	...	Between .65 per cent. and .75 per cent., keeping this as close to .70 per cent. as possible.

With proper heat-treatment such broaches should have a range of C63—C65 Rockwell.

When small quantities of components only are required, broaches can, of course, be made from case-hardened mild steel which will function satisfactorily, but they will require lighter cuts per tooth and such broaches will not give an equivalent life to high speed steel.

When cutting steel, a good finish will be obtained more easily on higher tensile materials than on those which are too soft as, with the latter, like all other machining operations, there will be a tendency to tear ; the best range is between 200 and 285 Brinell.

In this connection, where tearing results, improvement can often be effected by heat-treating the components to increase the Brinell. In general practice material up to 320 Brinell or Rockwell C35 is

within the broaching range, and during the recent war, alloy steels having a Brinell up to 444 or Rockwell C46 have been successfully broached with broaches manufactured from 18-4-1 material referred to.

Regarding life of broaches, it has been ascertained experimentally over a long period that this is much higher—usually not less than 50 per cent. and frequently over 100 per cent.—when used on hydraulically operated machines.

Cutting Speeds.

Cutting speeds vary over a wide range and the practice should be to keep these as high as possible, but usually known factors affect a choice of speed, and most mild-steel, cast-iron and brass can be machined up to 25 or 30 feet per minute, while on the other hand, some of the higher tensile alloys may require to be machined as low as 3 to 4 feet per minute to obtain a satisfactory finish and high tool life. Aluminium and magnesium should be cut at the highest range of speed possible, due allowance being made for any alloying constituents. The modern hydraulically operated broaching machine with its infinite range of speeds is ideally suited for dealing with various classes of material, as a suitable speed can soon be easily ascertained.

A valuable feature now being incorporated in some hydraulic machines is a variable two-speed cutting cycle. With this feature the roughing portion of the cycle can be made at high-speed, automatically reducing hydraulically for the finishing portion of the stroke. It is immaterial that the change takes place with the broaches in contact with the work.

The shock experienced by each tooth as it meets the work-piece must not be forgotten, and the nearer the stress approaches the ultimate strength of the broach itself, greater is the possibility of fatigue.

Coolant.

Like all machining operations the use of coolants in broaching is to keep the tool at a low temperature while cutting, and also as a lubricant, thereby reducing the power necessary for cutting. Chips are made to pass more easily over the cutting edge, thus increasing tool life, and at the same time minimising the freezing or sticking of the chips to the cutting edge of the broach—a factor more important perhaps in broaching than any other method of metal cutting. It may be taken as an axiom that the heavier the cut the greater the viscosity of the fluid required, and normally internal broaching calls for a more concentrated fluid than external broaching. The usual straight oils and soluble oils can be used, and sometimes a dilution

of the former by paraffin may improve results. The best cutting oils for broaching are those known as sulphurised, and several lubricant suppliers now market this type.

In dealing with materials of the stainless class the addition of carbon tetrachloride will usually be found advantageous. With steels of a lower tensile, brass and aluminium, a soluble base oil suitably diluted will be found the most satisfactory, while cast-iron can usually be cut dry, but in some circumstances a very light oil, or soluble oil may be used with a mixture of paraffin if high finish is of importance. More frequent re-grinding will be necessary, however, when a cutting fluid is used for cast-iron.

The volume and direction of the coolant are also important factors, as it is essential that the tool be completely and heavily flooded as close as possible to its points of contact with the work-piece. This is more easily dealt with on vertical machines than on the horizontal type. It is, of course, important that coolant fluids be kept clean by efficient filtering, as the presence of foreign bodies, such as fine chips or grinding dust, may damage not only the broach teeth, but also the machine ways.

Broach Maintenance and Preservation.

Broaching tools cannot be considered inexpensive in themselves, although the cost per work-piece is invariably much lower than any other form of cutting-tool. It must be admitted that in internal broaching, they are somewhat ungainly in the heavier and more bulky variety, and therefore special care should be taken to preserve their cutting edges.

It is often the case that effective life is reduced more by mis-handling than by actual cutting, and the provision of proper trays for carrying from section to section, also for storage in the tool-room, stores, or adjacent to the broaching machine, should be considered. Vertical or horizontal racks can be very cheaply constructed, or partitioned trays provided.

When sending broaches by rail or other transport, they should be well coated with vaseline or anti-rust preservative, and wrapped in grease-proof paper or cellophane, and for round broaches suitable cardboard tubes can be obtained quite cheaply for the purpose. In packing broach inserts, cardboard or wooden dividers should be used to prevent contact with each other.

Re-sharpening.

Here the golden rule is to re-grind at an early rather than a late stage. It is not economical to continue using the broach after the edges have dulled, because the life will be greatly reduced owing to the amount which will have to be removed from the front face or cutting edge, in order to bring it back to a suitable cutting condition.

On hydraulically operated machines the infallible test is the pressure gauge fitted to such machines, and the moment the load shows a definite and sustained increase, the time for re-sharpening has arrived, even though the cutting edges may still appear satisfactory to the naked eye. It is difficult to give actual figures, but any constant increase in load of over 20 per cent. should be looked upon with suspicion.

On mechanically operated machines the cutting edges should be checked from time to time with a magnifying glass.

Some hydraulic machines are now fitted with " Yale " locks on the pressure control, so that, having once ascertained the maximum load and made the appropriate pressure setting, the control can be locked and the machine, when overloaded relative to this setting, will then cease to pull, at once indicating that the broaches need regrinding. This offsets the tendency of some operators (particularly when on piece-work), to continue to use broaches which should be replaced or re-ground.

For round broaches, a broach grinding machine similar to that in Fig. 36 is almost essential, as with the universal head on this type of machine, the necessary cutting angles can be easily obtained.

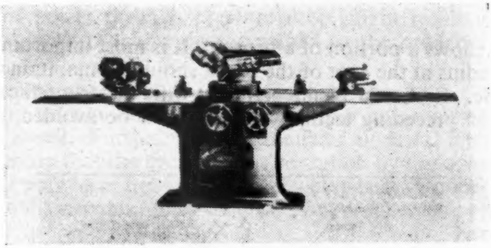

FIG. 36.

In this illustration will also be seen the Universal work-head, having live and dead centres, tailstock, broach supports and magnetic chuck.

Many surface broaches, however, can be satisfactorily dealt with on ordinary surface grinding machines, especially if equipped with a Universal magnetic chuck, but it is often an economy to employ simple bolsters or fixtures into which the broach inserts can be placed, automatically giving the correct relation of the cutting edges to the locating faces of the broach.

Fig. 37 illustrates a standard surface grinding machine being used for one of the re-grinding operations on a surface broach insert, mounted on a Universal magnetic chuck.

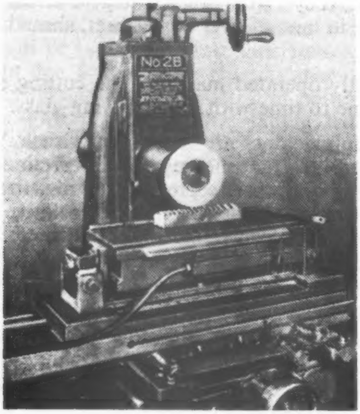

Fig. 37.

Fig. 38 shows a portion of a broach. It is most important that the original radius at the root of the tooth should be maintained as near as possible. It should blend perfectly with the front face and the back of the preceding teeth. "Steps" must be avoided, otherwise

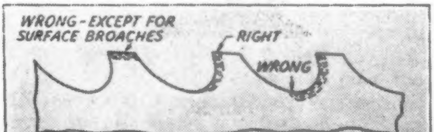

Fig. 38.

chips will be given a tendency to crowd—a certain method of causing tooth breakage. In general, the front face is the only part that should be re-ground, and its original angle should be maintained. It should be completely cleaned up, leaving no witness, but excessive re-facing should be avoided as this reduces the effective life of the broach.

The number of permissible re-grinds will vary from 8 to 15, depending upon the material being cut and, of course, on the amount

of work to which the teeth have been subjected. The top rake and clearance angle should not be interfered with unless the broach has to be reduced for another size of component, when the width of land, its angle and clearance angle should be reproduced.

When re-grinding round, splined or similar broaches, cup or saucer wheels should be used for face grinding, as face corrugations, due to wheel wear, are less likely to be produced than when using disc wheels. Alternatively, if a disc wheel is used, it must be in a Universal head, so that the periphery and not the side of the wheel is cutting.

Fixture Design.

In surface broaching, equal in importance to broach design is that of fixture design. Broaching being relatively such a rapid operation so far as actual cutting is concerned, it is obvious that to minimise the complete floor to floor cycle time, great attention must be given to ease and rapidity of loading and unloading the components, also to the handling of these before and after the operation.

With hydraulic machines, clamping can often be effected by hydraulically actuating the moving members of the fixtures. The combination of hydro-mechanical operation is to be preferred to that of depending only on the hydraulic circuit for clamping, because any loss of power through pressure drop might result in a loose component, with probable drastic results to the broaches or other equipment.

It is comparatively easy to ensure that the final clamping is obtained by mechanical means, although put into operation by the hydraulic circuit. Furthermore, hydraulic or electrical interlocks are usual to ensure that the cycle cannot be started by the operator until the components have been satisfactorily clamped. Hopper or chute feeds are used where a great number of components are produced per hour.

If variation in the deflective forces during broaching cannot be avoided, an attempt should be made to minimise these as much as possible, otherwise low broach life may result. The ideal condition to be aimed at is to introduce forces in the component equal to the maximum broaching forces before the broaching operation commences. This principle, known as pre-stressed clamping, is always to be recommended, but it is not always possible to adopt, owing to the particular shape and design of the part to be broached. The variation of the cutting forces acting upon the fixtures are the same as are present in the broach holder, and therefore it is essential that the maximum possible mass is built up into the fixture to absorb any small vibration that might result.

It has been found by experience that if the greatest consistency

is to be obtained from a broaching operation the fixture clamping forces must be applied consistently. The particular broaching application is the controlling factor, and therefore without quoting definite examples in detail, little can be said. It should be noted that the automatic clamping feature as recommended for cutting efficiency is also a feature for production efficiency since, with this, the only action the operator has to perform is to load and unload the work-piece in the fixture, thus reducing fatigue. Where a very high production rate is required, and automatic clamping or indexing fixtures are used, the operator can often load the work-piece during the broaching cycle, the broached work-piece being automatically ejected.

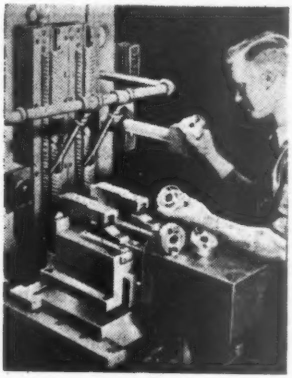

FIG. 39.

Fig. 39 illustrates a set-up where the components are mechanically secured, but the mechanism hydraulically operated through the shuttling of the table. This example is a forged carbon steel machine-gun part, broaching being performed on four surfaces in two stations at the rate of 360 components per hour.

FIG. 40.

Fig. 40 is a typical example of chute feed in which nickel chrome steel pole pieces (as shown in inset) are being machined at the rate of 1,600 pieces per hour, four pieces being clamped simultaneously for this operation. The blanks are fed in from the chute seen in the centre, and automatically ejected into a tray on the left side of the machine. The fixture shuttle slide is interlocked with the broaching slide and the latter cannot start its downward movement until the shuttle slide and components are in the correct broaching position. The return part of the cycle is similarly interlocked during ejection of the completed components.

Before concluding, a few further examples of broaching practice will be described.

In Fig. 41 a standard horizontal broaching machine—a portion of which can be seen on the right—has had built on to it a special extension consisting of a broach holding and supporting fixture, in which is incorporated means of holding a four-cylinder engine block.

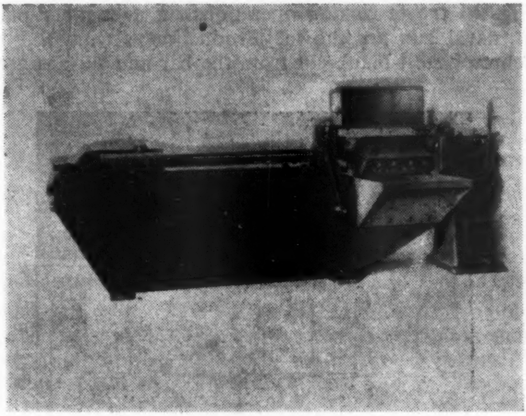

FIG. 41.

The operation is that of broaching the camshaft bearings, and production is 100 completed blocks per hour.

The block is slid into position from the table at the front, whereupon a special puller passes through the camshaft bores, engages the broach and reverses to commence cutting. At the end of the broaching stroke the block is removed on to a table at the rear ; the machine then returns the broach to its original position, the broach puller retracts and thus allows loading of the next component.

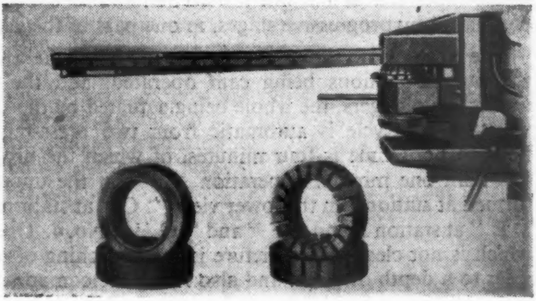

FIG. 42.

Fig. 42 shows an interesting set-up on a

hydraulic broaching machine, cutting slots $1\frac{1}{16}$ in. deep by ·153 in. to a tolerance of ·0002 in. in cast-iron speed-reducer rings $4\frac{1}{2}$ in. diameter. The thin wall left at the bottom of the component following broaching is noteworthy, in view of the fine tolerance to which the width of the slot has to be held. Fourteen components per hour are produced.

In Fig. 43 the broaching operations on a hammer plate for a 20 mm. naval gun are shown. Production is from a 3 per cent. nickel-chrome steel blank cut from the bar and surface ground. A

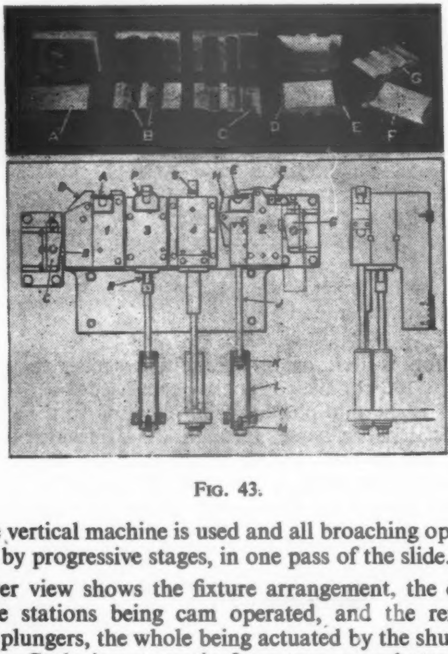

FIG. 43.

single-slide vertical machine is used and all broaching operations are completed by progressive stages, in one pass of the slide.

The lower view shows the fixture arrangement, the clamping at the outside stations being cam operated, and the remainder by adjustable plungers, the whole being actuated by the shuttling of the work-table. Cycle is automatic from two press-buttons, and the floor to floor time is four minutes, of which the broaching time is less than one minute. Operation " B " in the upper view is performed at station 1 in the lower view, " C " at station 2, " D " and " E " at station 3, and " F " and " G " at No. 4. Operation " G " which is not clear in the picture is the broaching of a step on both sides to a depth of $\frac{3}{32}$ in. and also sizing the component to width.

The next examples are the various spar boom components used in the wing construction of a British aircraft, as shown in Fig. 44.

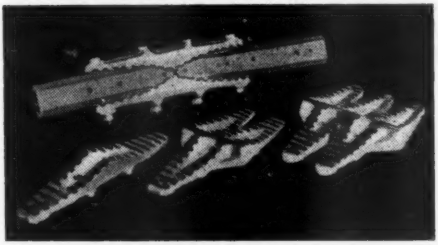

FIG. 44.

The different types of plates will be seen in the lower portion of the picture, while above can be seen booms and single-type plates assembled.

The booms are actually 15 feet long and broached at both ends, being foreshortened and shown single ended in the picture for convenience. Too many views would be required completely to illustrate the methods used, but with a drawing of the broaches used on the boom it will be possible to describe the operations.

The plates are produced by similar means and, like the boom, one half at a time and then indexed through 180 degrees. In addition, the booms have to be turned end for end, as there are four operations on this component. Extreme accuracy is essential as all plates, booms and their spares, must be interchangeable.

At the fuselage end of the aircraft the wing commences with three booms, leading to two, and finally to one, as will be seen from the illustration.

Standard single-slide vertical machines are used, the one for the booms being augmented by an outboard cradle fixture which is long enough to accommodate the component throughout its length, indexes at 180 degrees, and then accurately locates the opposite end for the third and fourth operations. The component is withdrawn laterally after each face has been cut and before the return of the broach slide.

For the plates, separate fixtures are provided for each type, and are attached in turn to a common jig which rotates in two planes to present the correct faces for machining. The table shuttles to and from the broach slide at each cycle.

All operations on both machines are interlocked so that it is impossible to start the cycle until the components are correctly positioned.

The components are of light alloy, having cutting characteristics similar to mild steel. The boom is previously rough milled, leaving

·020 in. for broaching, while the plates are completely broached in two cuts per face.

Fig. 45 shows a sketch of the broach bar and broaches used for the boom. The profile form is divided into two stages at "C" and "D" to reduce load, and teeth are nicked to break up chips. The

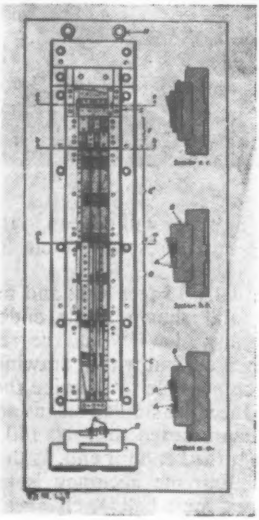

FIG. 45.

grooves are rough formed at "E" and their tops chamfered at "F." The broach inserts are retained in the bar by taper wedges.

The finishing broach seen at "G" has lateral screw adjustment for accurate positioning in relation to the roughing cut. Floor to floor production of booms—four faces—is 8·5 minutes, and plates —two operations per piece—is 2·75 minutes.

Owing to the relatively fragile nature of most cylinder block castings, special consideration must be given to the total pressure which the casting will withstand from both the clamping and broaching forces, and therefore the supporting fixture and the arrangement of the broaches must be such that the ultimate strength of the casting will not be approached. The problem is further complicated by the necessity to remove the maximum amount of metal in the minimum time, while still producing a satisfactory degree of accuracy and finish.

In Fig. 46 will be seen a special horizontal machine for broaching the bottom faces and the bearing cap seats in either six or eight-cylinder cast-iron cylinder blocks. The broaches, which are in the

vertical plane are of inserted blade type, the picture showing the loading position. The block is slid from the conveyor track into the

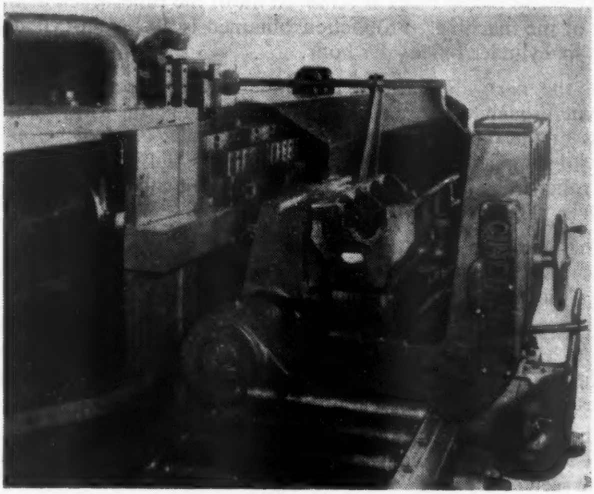

FIG. 46.

fixture, where it is positioned against lugs and clamped. Hydraulic mechanism then swivels the fixture and block into the broaching position, as shown in Fig. 47.

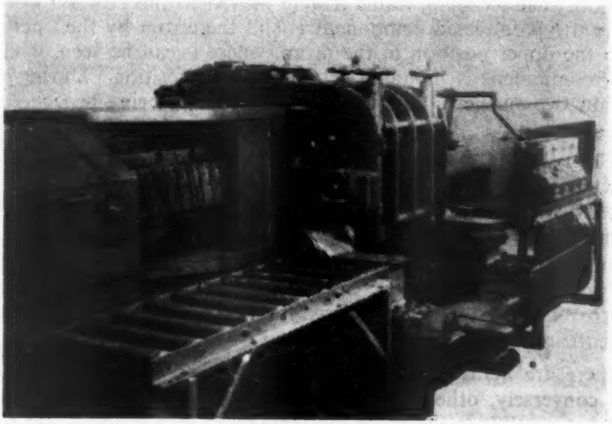

FIG. 47.

The broaching stroke having been completed, the fixture and block are returned to the loading position. The broach slide returns and the completed block is removed on to the roller track at the far end of the machine. Production obtained is 50—eight-cylinder, or 55—six-cylinder blocks per hour.

In the next illustration—Fig. 48—another type of machine is shown broaching the crankshaft half-bearing, the cap seats, and sides of the oil filler seats. The block, which is of cast-iron, and previously machined on the bottom face, is slid into position from the roller-track, and located by an equalising end stop and locating dowels. Clamping is by hand from the two levers above.

The operation is progressive, the half bearing first machined, then the cap seats, and finally the oil filler cap seats. The production on six-cylinder blocks is 50 per hour.

Fig. 49 is a view of a machine for broaching cast-iron cylinder heads, the top and bottom faces of which are simultaneously broached progressively on a horizontal machine with broaches of inserted tooth type, which are held in the vertical plane.

The components are held in a drum-type fixture which indexes each 90 degrees. A completely finished head is delivered into the chute seen at the right, while a component already machined on one face enters the swinging and counter-balanced frame, also seen at the right, but when this is at 90 degrees to that shown in the illustration. The ejection of both components is hydraulically performed by a pusher, the ram for which can be seen to the left of the push-button station. The swinging frame having moved to the position shown, the partly completed component is slid therefrom by the operator into the upper position in the drum, where it can be seen, while a new component is mounted into the lower position. During this period two further components are, of course, being broached on the opposite side of the drum. Production : 77 pieces per hour.

The difficulty of completing a comprehensive survey or broaching practice in the space at my disposal will no doubt be obvious, as many of the detailed subjects dealt with could quite easily form the subject of a paper in themselves.

In former times there was a tendency to make comparison between milling and broaching practice, but in the light of experience, this controversy has rightly faded away, it now being recognised that each have their particular spheres, governed by a variety of conditions.

There are many cases when broaching only can be considered, and conversely, others where milling would be more satisfactory. It is not possible in the space available to go into the pros and cons

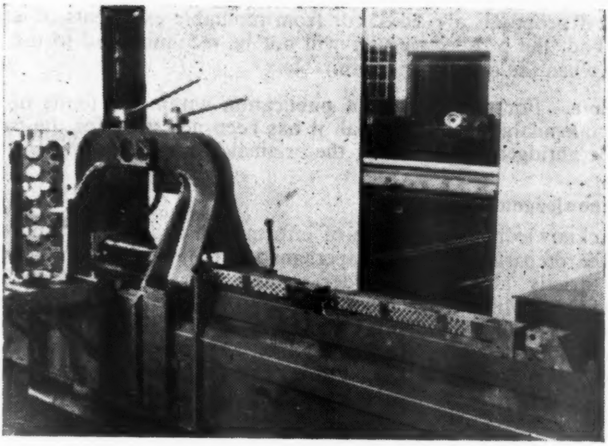

FIG. 48.

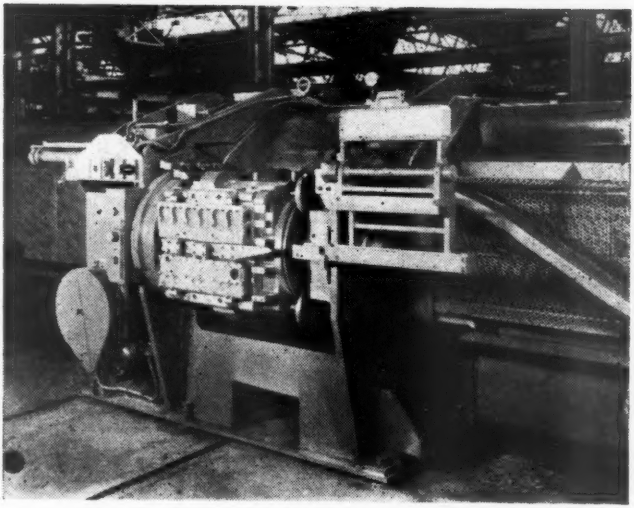

FIG. 49.

of these alternative methods of machining, but it can be safely said that if proposals are asked for from reputable exponents of either method, the prospective user will not be recommended to use the one when the other is more suitable.

Note.—For the purpose of publication within the limits of the space available in the Journal, it has been necessary for the paper to be abridged, and some of the original illustrations omitted.

Acknowledgments.

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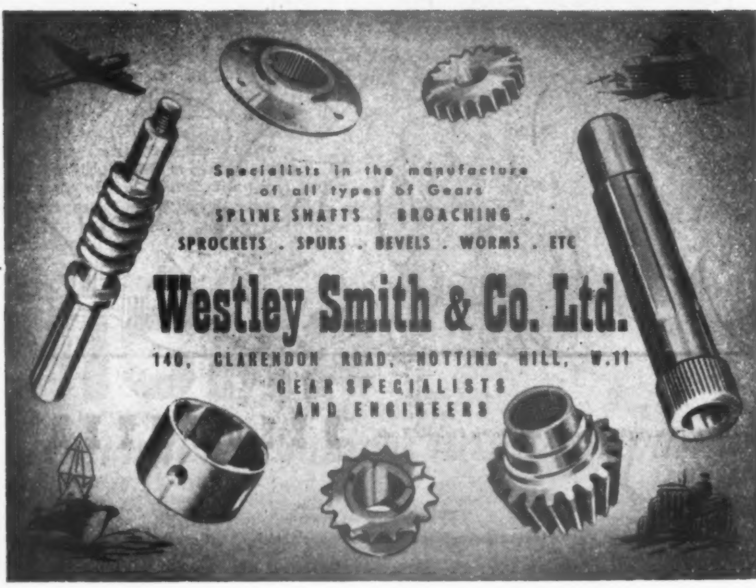

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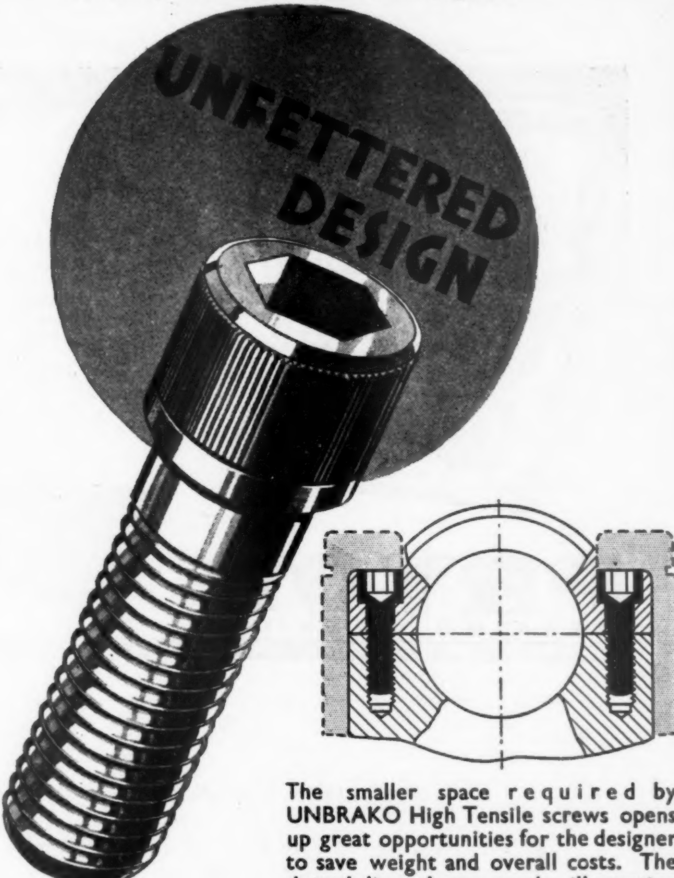
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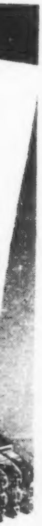

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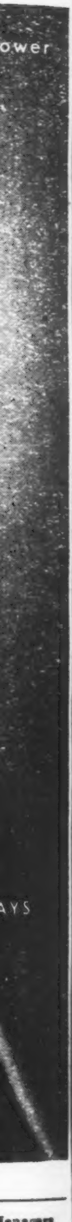

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